COMPUTATIONAL PHYSICS FOR ACCELERATORS

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Accelerating Science

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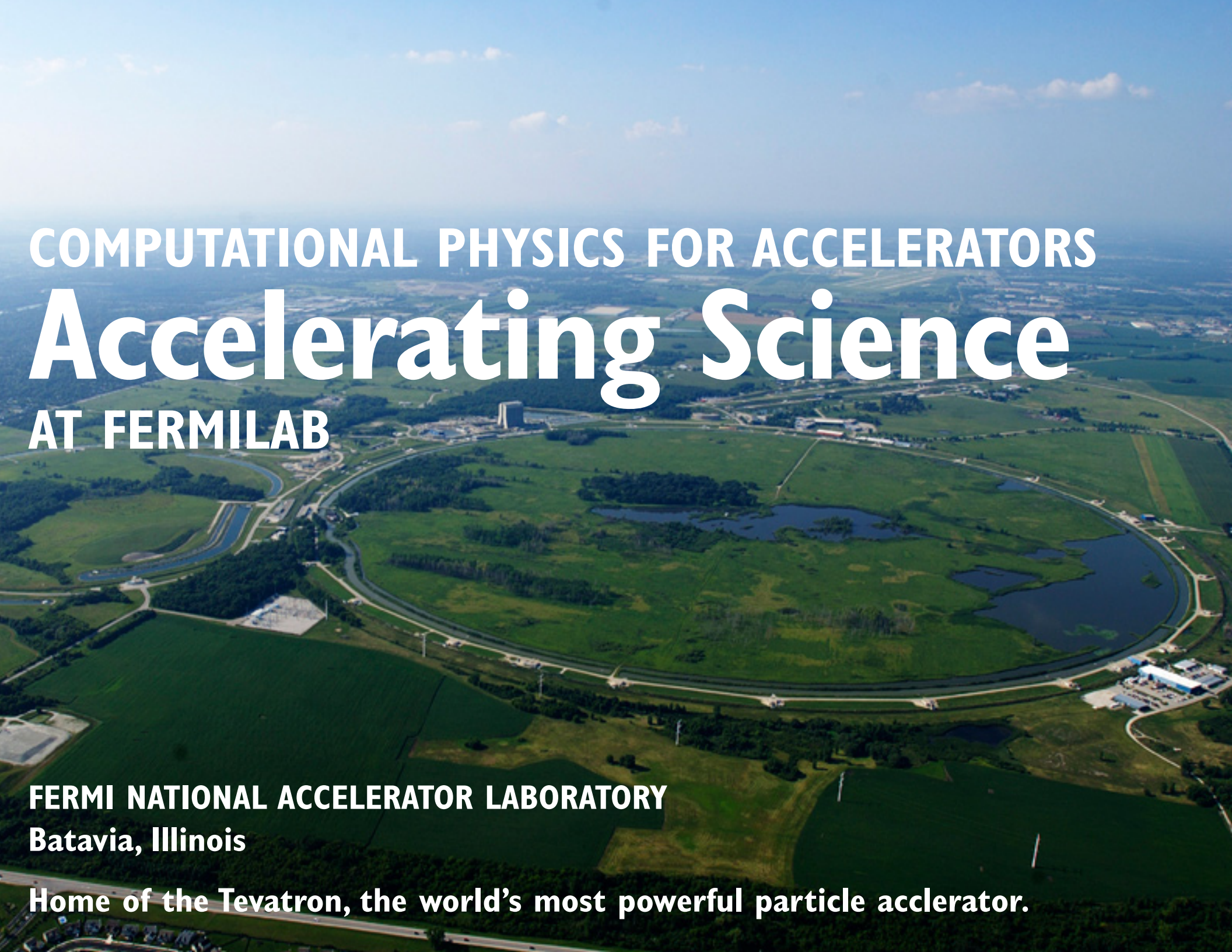
Accelerating Science

AT FERMILAB



COMPUTATIONAL PHYSICS FOR ACCELERATORS

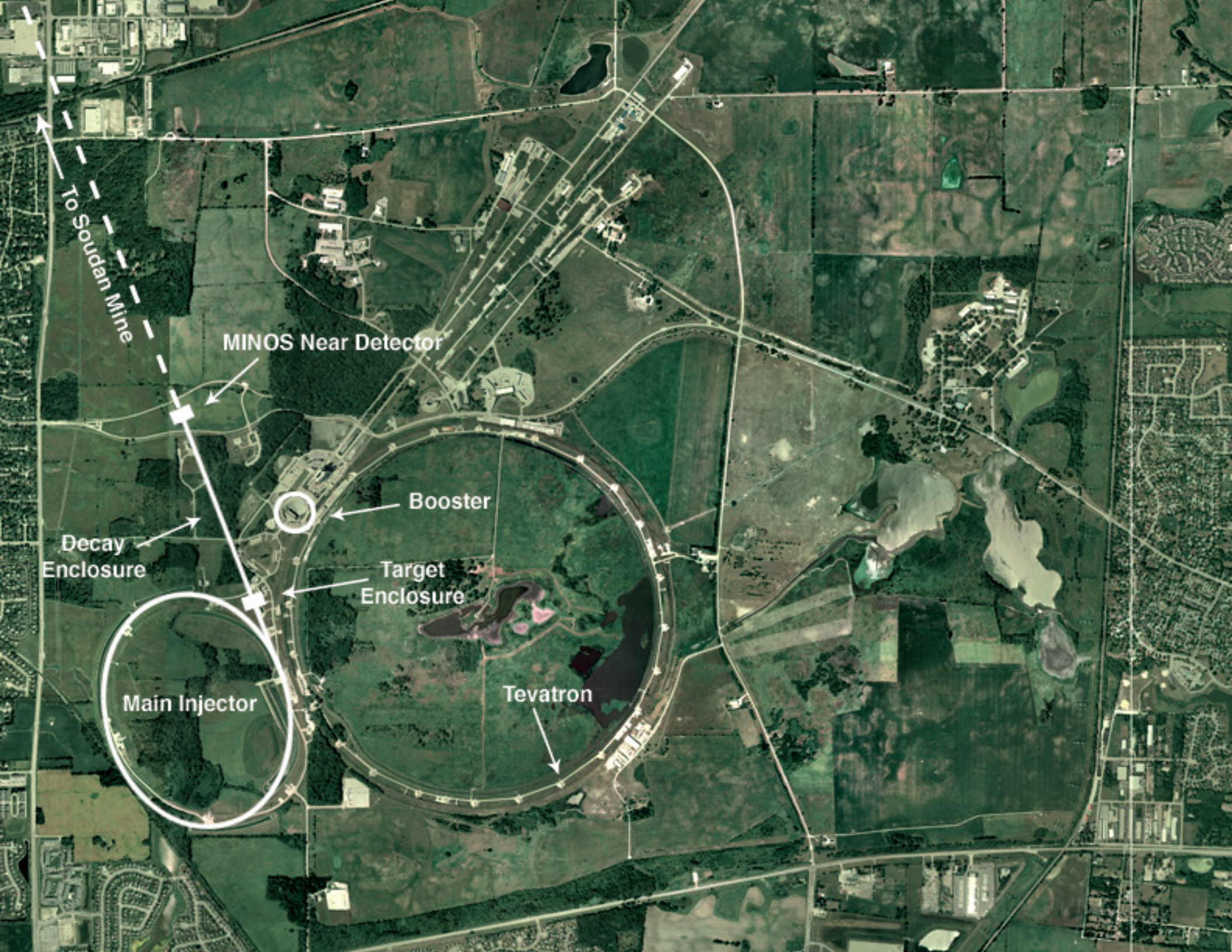
Accelerating Science

AT FERMILAB

FERMI NATIONAL ACCELERATOR LABORATORY
Batavia, Illinois

Home of the Tevatron, the world's most powerful particle acclerator.

Booster and Main Injector


To Soudan Mine
MINOS Near Detector
Booster
Decay Enclosure
Target Enclosure
Main Injector
Tevatron

What are accelerators good for?

What are accelerators good for?

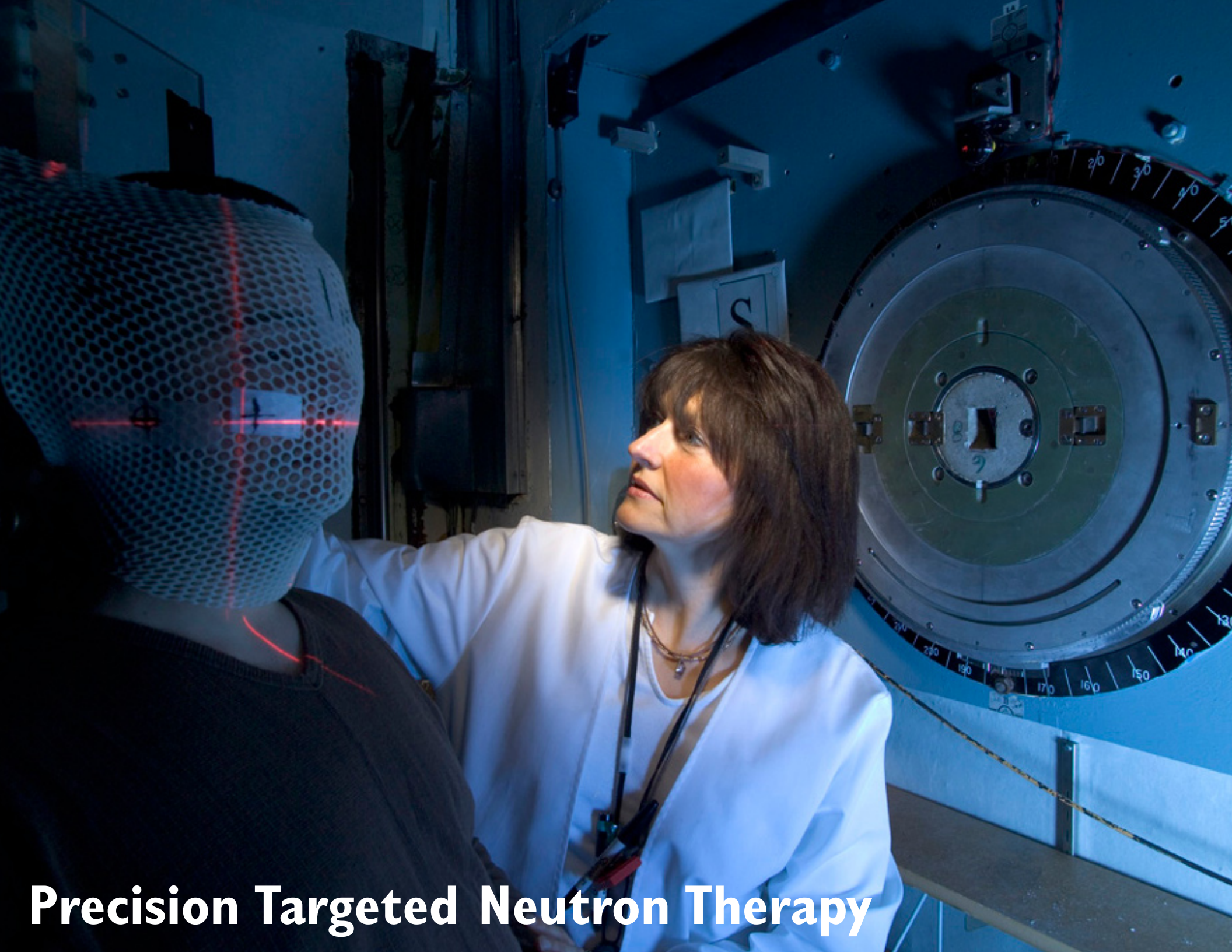
Medical Applications—cancer-therapy

Materials Science—structure of materials

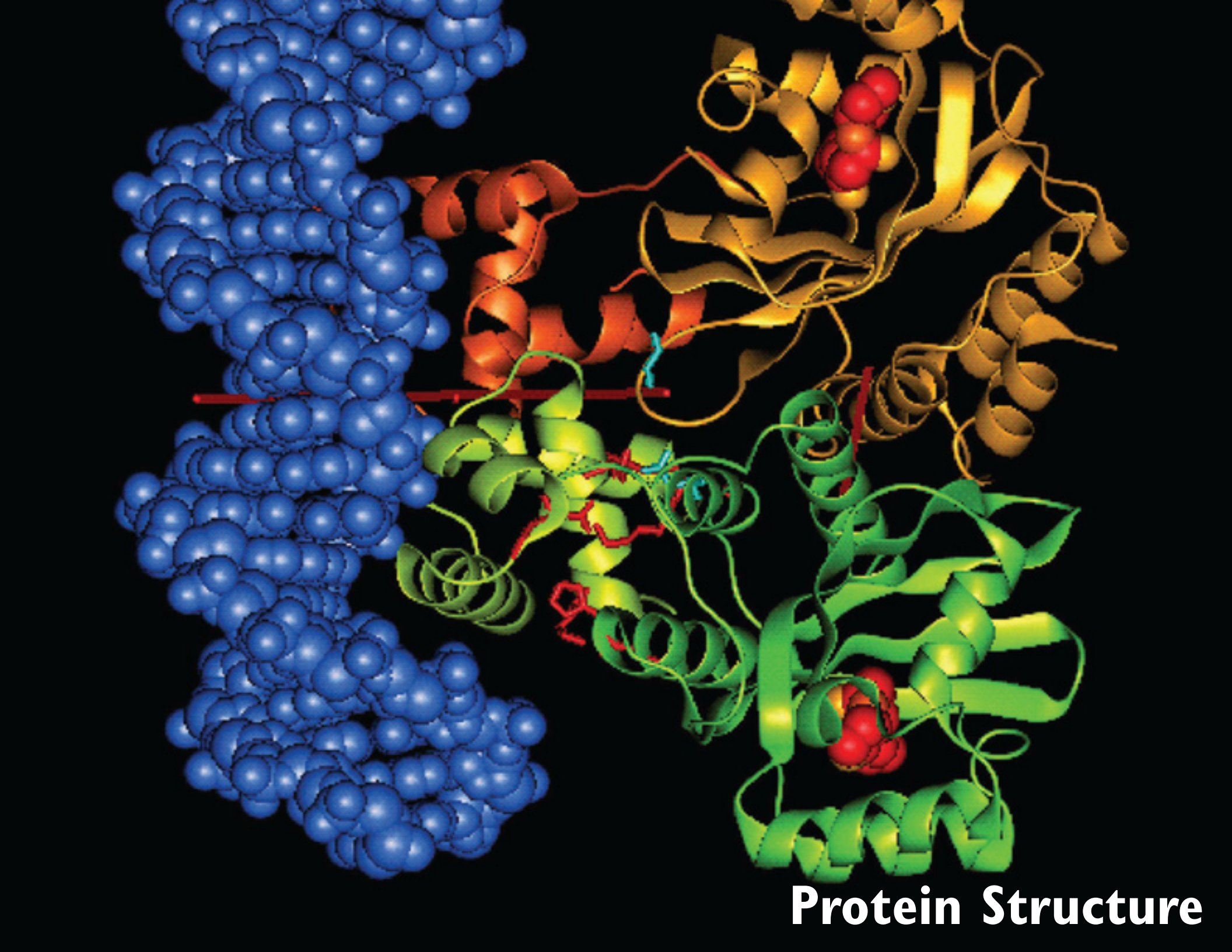
Biology—resolve fine details of biological systems

Nuclear Physics Research—heavy ion, dense matter

Particle Physics Research—Higgs, new particles, dark matter



Precision Targeted Neutron Therapy



Protein Structure

Accelerator simulation gives you…

Accelerator simulation gives you...

Faster—design, commissioning

Cheaper—simulate, don't prototype

Better—explore new ideas, enhancements

Main control room

Tevatron tunnel

Where are accelerators used?

Where are accelerators used?

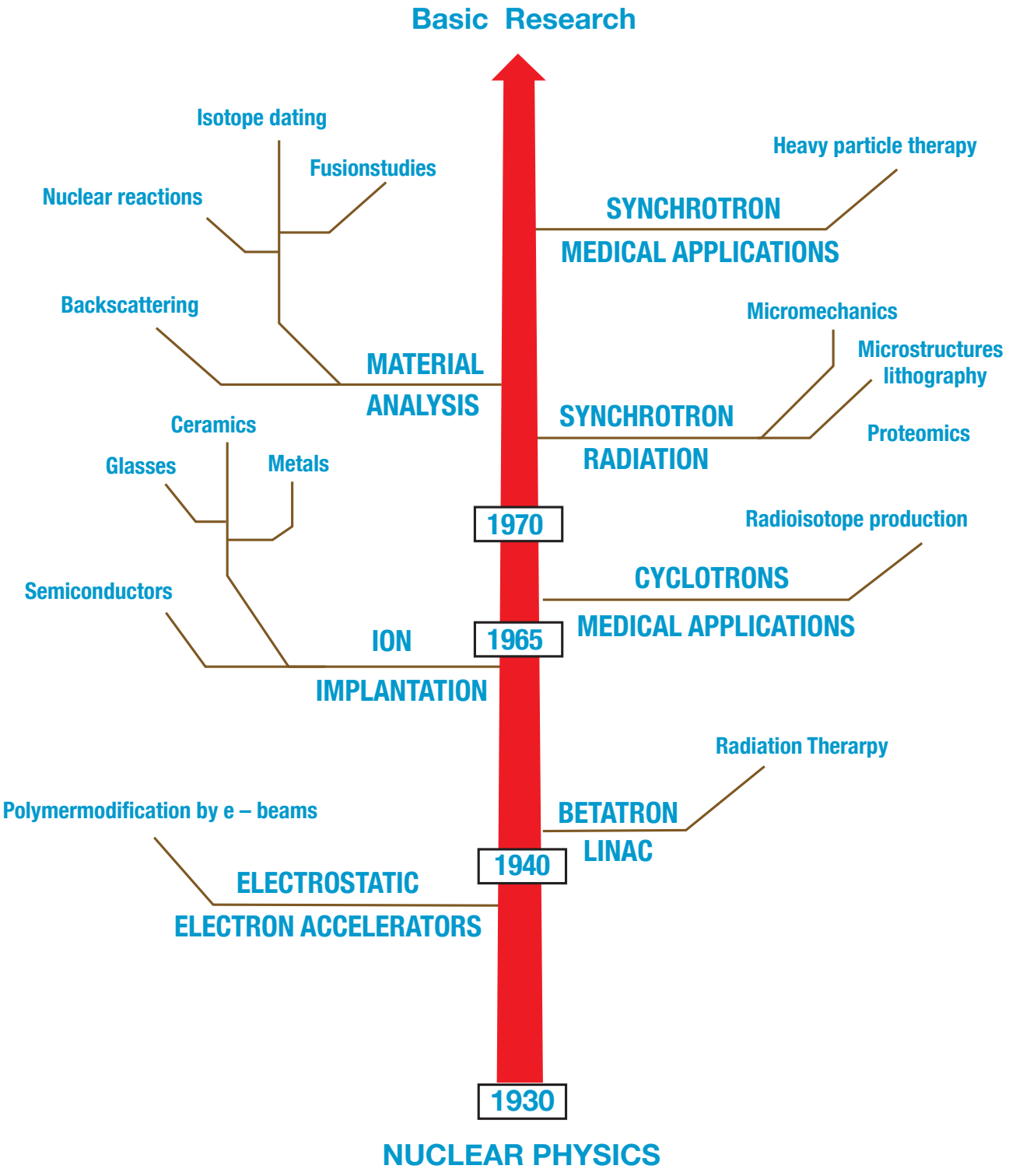
Atomic physics—Atomic collision processes, study of excited states, electronion collisions, electronic stopping power in solids

Condensed matter physics—Xray studies of crystal structure; Neutron scattering studies of metals and crystals, liquids, and amorphous materials

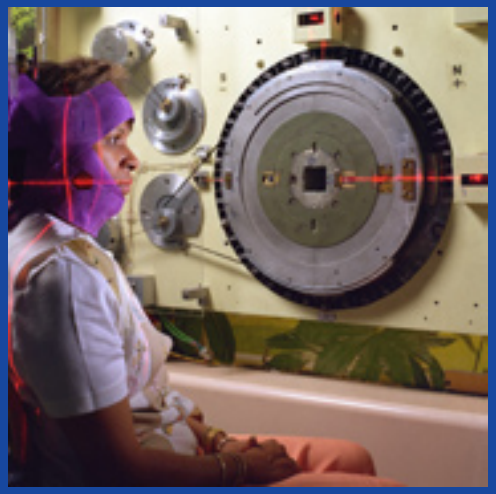
Material science—Proton and Xray activation analysis of materials; Xray emission studies; accelerator mass spectrometry

Chemistry and biology—Chemical bonding studies: dynamics and kinetics; protein and virus crystallography; biological dynamics

Medicine—Radiation therapy


Basic Research
Isotope dating
Fusionstudies
Nuclear reactions
Heavy particle therapy
SYNCHROTRON
MEDICAL APPLICATIONS
Backscattering
Micromechanics
Microstructures
lithography
MATERIAL
ANALYSIS
SYNCHROTRON
RADIATION
Proteomics
Ceramics
Glasses
Metals
1970
Radioisotope production
CYCLOTRONS
MEDICAL APPLICATIONS
Semiconductors
ION
IMPLANTATION
1965
Radiation Therarpy
Polymermodification by e – beams
BETATRON
LINAC
1940
ELECTROSTATIC
ELECTRON ACCELERATORS
1930
NUCLEAR PHYSICS

Cancer treatment with hadron therapy



Laser targeted
neutron therapy

Treament of
squamous
cell carcinoma

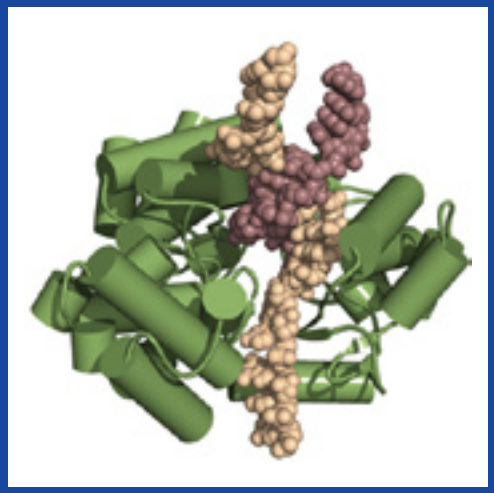
Before

After (two years)

Images courtesy of Fermilab

Resolve structure of biological agents at synchrotron light sources

Structure of two proteins involved in the development of cancer and aging elucidated by x-ray crystallography at the NSLS, Brookhaven National Laboratory by a group from the Wistar Institute and Johns Hopkins University.

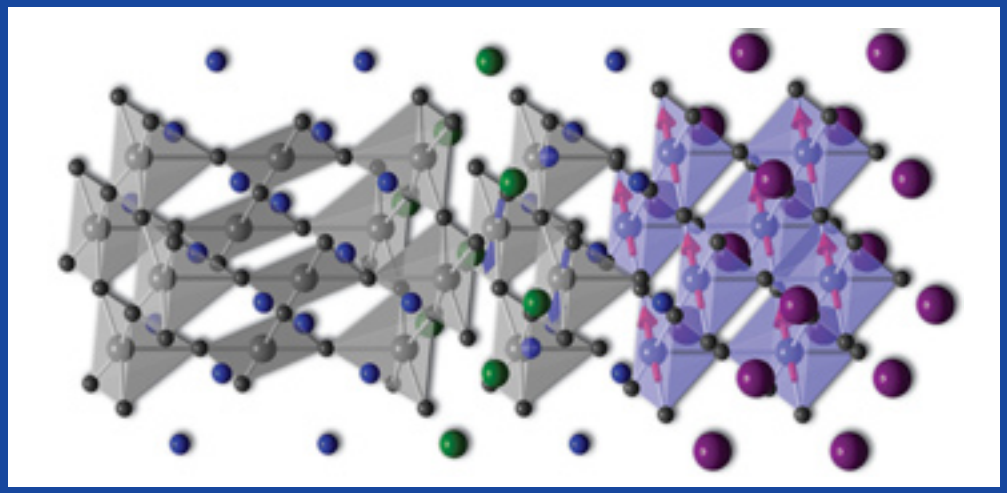


Telomerase

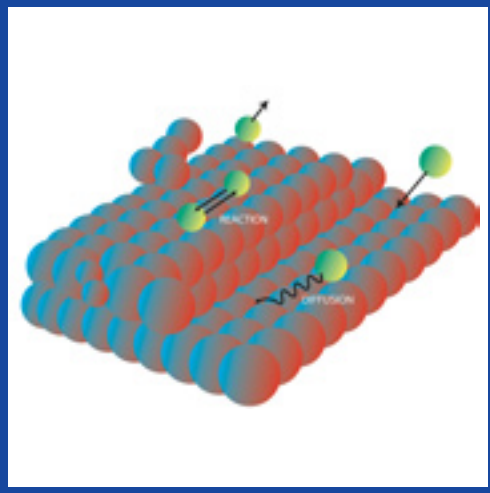
Histone acetyl transferase

Images courtesy of NSLS, Brookhaven National Laboratory

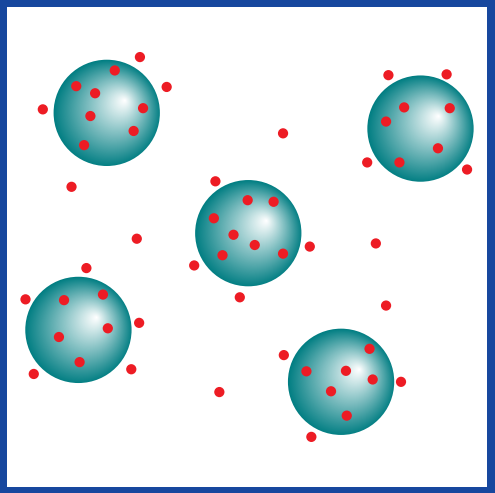
Materials science at synchrotron light sources



Crystal and magnetic structure at the interface between ferromagnetic and superconducting oxide



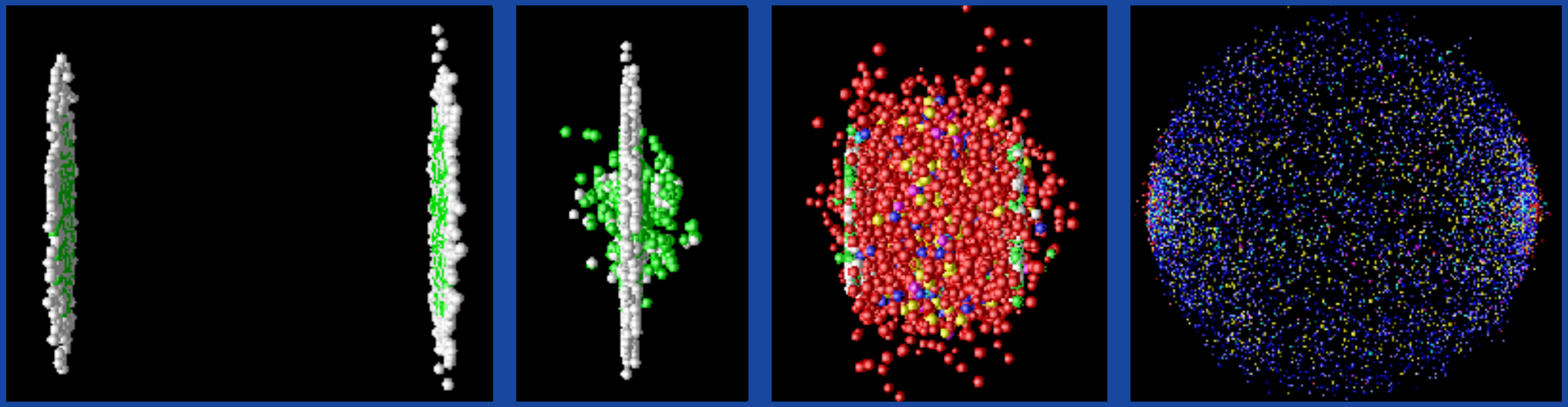
Surface properties studied at the Advanced Photon Source



Nanoparticle halo around microspheres in colloidal solution

Images courtesy of Argonne National Laboratory

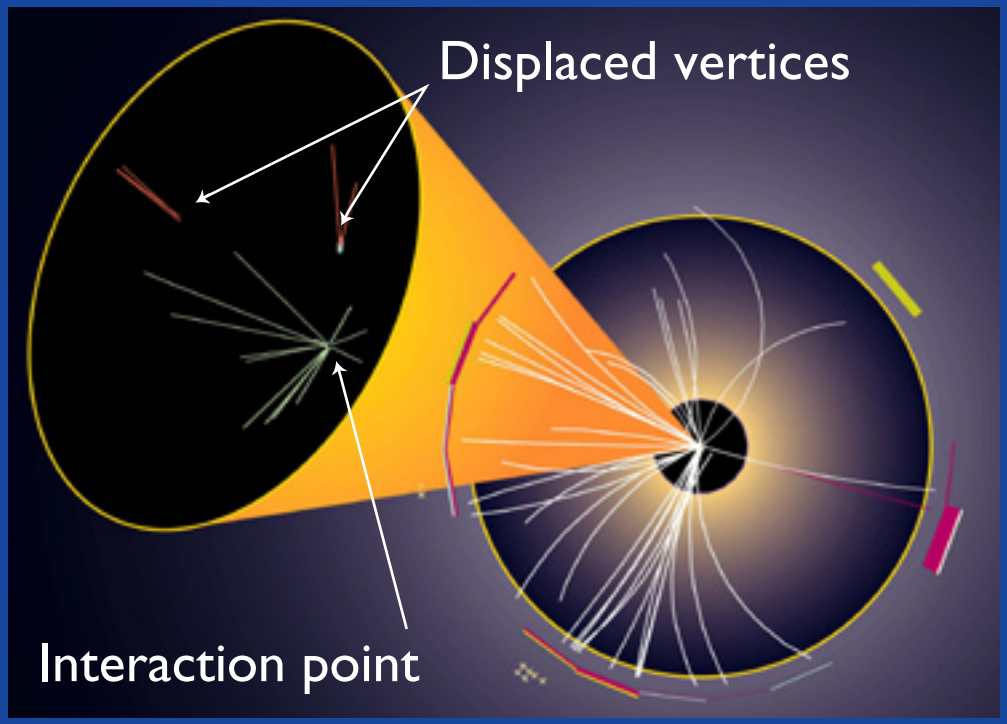
Nuclear Physics Research



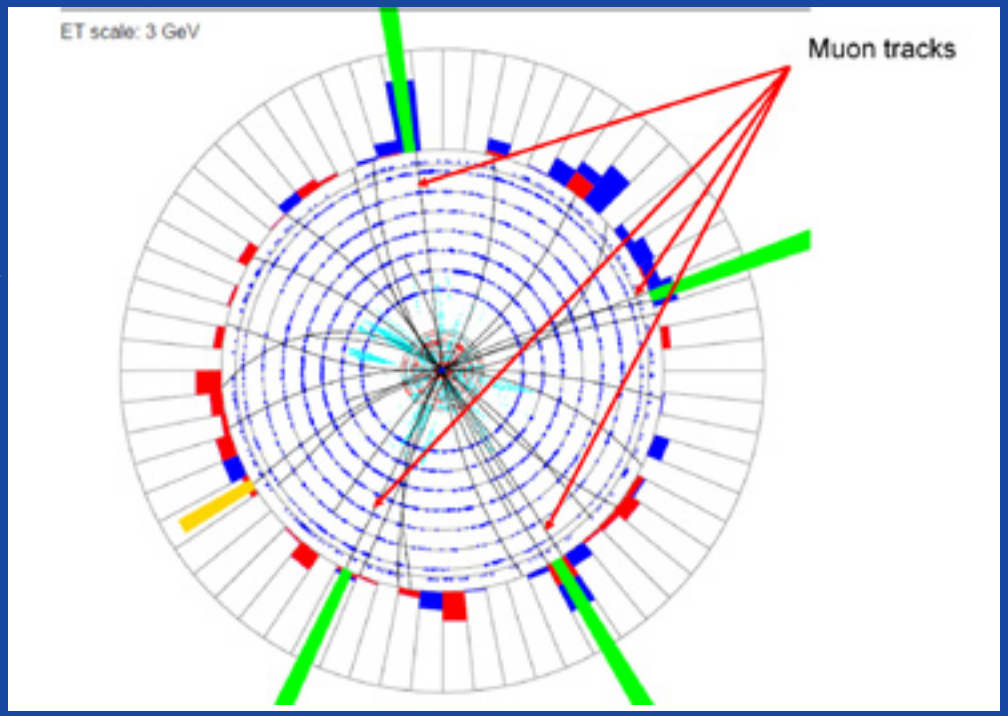
Gold-Gold nucleus collisions and
production of quark-gluon plasma

Images courtesy of Brookhaven National Laboratory

Particle Physics Research



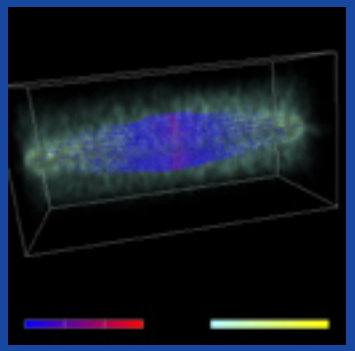
CDF t quark pair event showing both quarks decaying into B mesons marked by the decay vertices displaced from the interaction point shown in the magnified central track region.

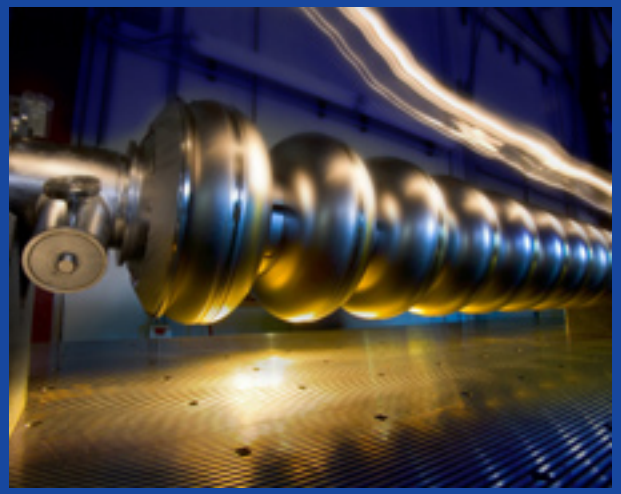


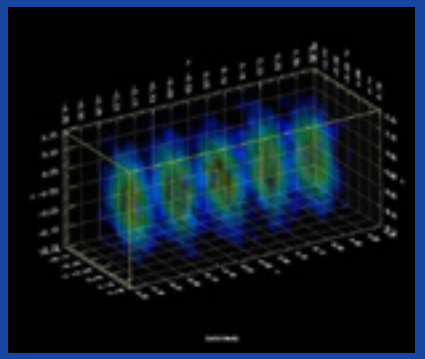
A ZZ event recorded by the DZero experiment at Fermilab. Each Z boson decays into a pair of high energy muons indicated by the green towers.

Images courtesy of Fermilab Visual Media Services

Particle Physics Research



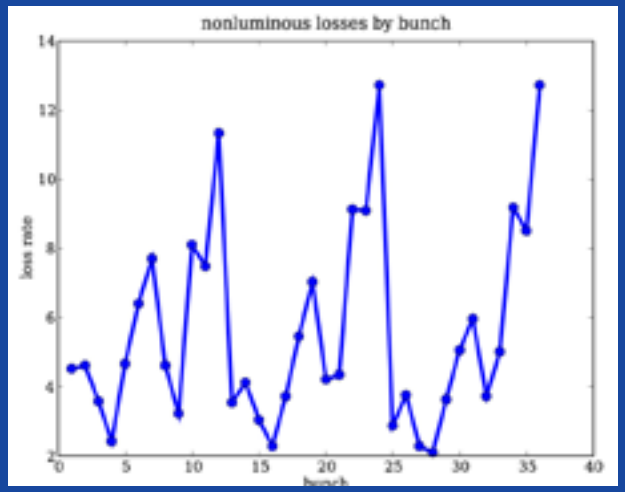




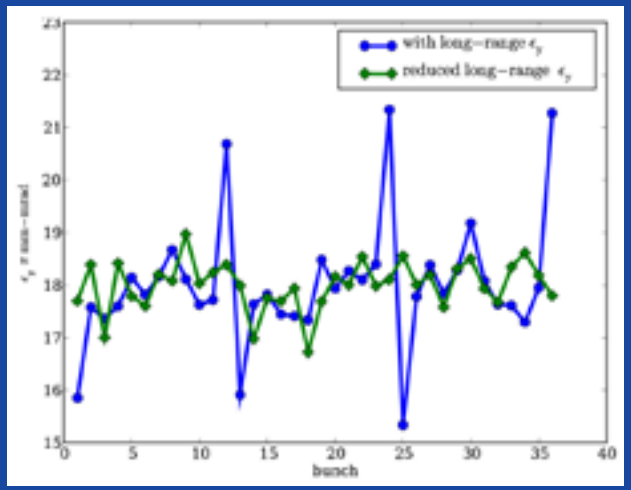
All of these accelerator applications will need to depend on computer simulations for the design and understanding of new accelerator components, techniques, and improved performance.

Beam-Beam Effect at the Fermilab Tevatron

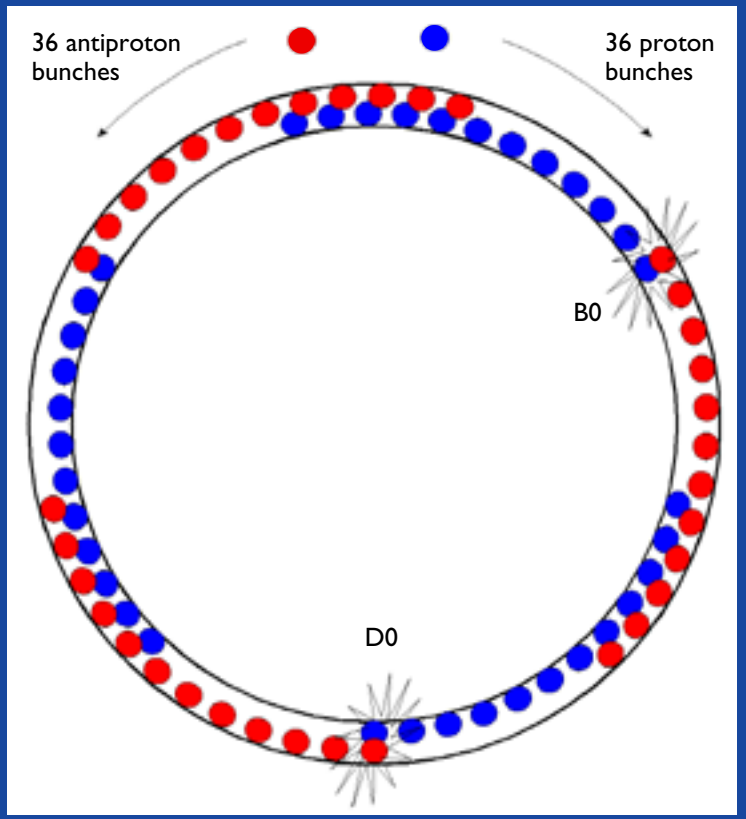
Measured losses



Computed beam blowup



Tevatron ring



Electromagnetic interactions between bunches cause spreading and loss efficiency.

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